Unit-1

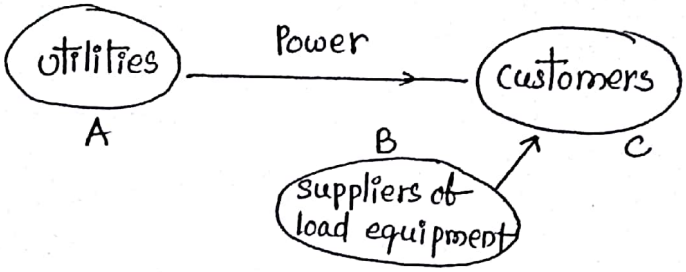
(1) What is power Quality?

- Any power problem manifested in voltage or current or frequency, that results in failure or mis-operation of customer equipment.
- Power Quality means, which has those characteristics enable the equipment to work properly.
- The level of power Quality required is that level which will result in proper operation of equipment at particular facility.
- Power quality ≃ voltage Quality
  - The Quality of voltage that is being addressed in most cases as the Qaality of power.
  - P = VI
  - 'I' depends on load so there is no control over the currents at generation stations.
  - so the standards in power quality are given to maintainning the supply voltage with in certain limits.
- Ac power systems are designed to operate at sinusoidal voltage of a given frequency (50 Hz) and magnitude so any significant deviation in the wave-form magnitude, frequency cause power Quality problem.
- Sometimes ~~we have~~ need to maintain the current at certain limits because the current passing through the system impedance can cause non sinusoidal voltage at receiving end
  - the current resulting from a short ckt.

- causes the voltage sag or disappear completely
- current from lightning strokes cause insulation failure
- Harmonic currents cause distorted voltage at receiving End.

② concern about power Quality:

- The ultimate reason is economic value
- There are ecomic impacts on utilities, customers, and suppliers of load equipment



- The Quality of power can have a direct economic impact on many industrial consumers.
- Now a days industries are using modern equipment, those are electronically controlled so they are more sensitive to deviations in the supply voltage.
- So all A,B,C are must aware of minor disturbances in power system.

A → generation stations (Power suppliers)

B → Semiconductor manufacture industry fans, lights etc. suppliers

C → Load (Customers)

- The electric utility (A), and B are concerned about power quality issues as well
  - meeting customer expectations and maintaining customer confidence-

- Lot of competation between utilities
- The loss of a disgruntled (dissapointed) customer to a competing power supplier can have a very significant impact financially on a utility.
- If number of complaints increase, then automatically staff in care centers should increase to handle them. This is indirect ~~ecomin~~ economic burden to A and B

- customers used to ~~by~~ ~~buy~~ buy devices or equipments with less cost and additional features that equipment should withstand common disturbances so supplieas ~~of~~ load equipment should ~~take~~ concern about this.
- Since many customers are unaware of the standard of equipment and supply, one useful service that utilities can provide is giving information on power quality and the requirements of load equipment to properly operate.

(3) General classes of power Quality :-

i) conducted low frequency phenomena :-

- voltage variations
- voltage Imbalance
- waveform distortion
- voltage fluctuations
- power frequency variations
- Induced lowfrequency voltages
- harmonics, Inter harmonics
- DC In AC supply.

ii) Radited low frequency phenomena :-

- magnetic fields
- ~~electric fields~~

iii) conducted high frequency phenomena :-

- Induced continuous wave voltages or currents
- unidirectional transients
- oscillatory transients

iv) Radiated high frequency phenomena :-

- magnetic fields
- Electric fields
- Electro magnetic fields
- continuous waves
- Transients.

v) Electro static discharge phenomena :-

vi) Nuclear electro magnetic pulse :-

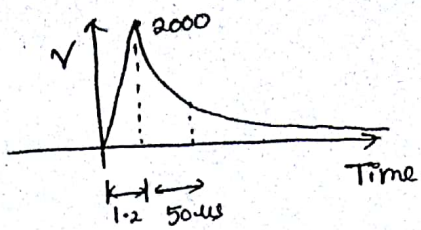
④ Transients :-

- The term transients used in the analysis of power system variations to denote an event that is undesirable and momentary in nature.
- The part of the change in the voltage or current during transition from one steady state operating condition to another steady state.
- Anything unusual that happens on the power system is called transients.
- Transients are two types
  - Impulsive transient
  - oscillatory transient.

- Impulsive transient :-
  - An Impulsive transient is a sudden change in steady-state condition of voltage, current or both that is "unidirectional" polarity. ("either positive or negative")

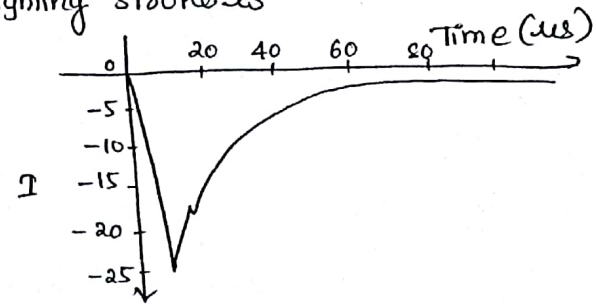
- Impulsive transients are normally characterized by their rise and delay times.

Ex: 1.2 × 50-us / 2000 volts



rise time t_r = 1.2 u
delay time = 50 u

- The most common cause of Impulsive transients is lightning.
- A typical impulsive transient caused by lighting stroke is



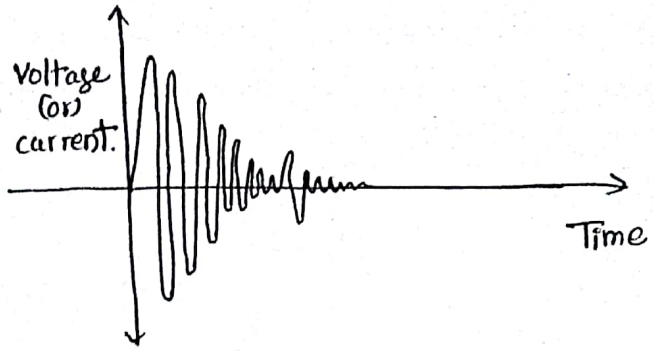
- Transient Impulsive
  - Nano second Impulsive transient (T_r = 5 ns)
  - microsecond T_r = 1 us
  - milli second (T_r = 0.1 ms)

- **Oscillatory Transient :—**
  - oscillatory transient is a sudden change in the steady state of voltage or current or both that includes "both positive and negative" polarity values.
  - An oscillator transient consists of a voltage or current whose instantaneous value changes its polarity rapidly.
  - oscillatory transients
    - low-frequency
    - medium freq
    - high-frequency

- causes for
  low frequency oscillatory transients → capacitor Bank energigation

  medium frequency → Back to Back capacitor energigation

  High frequency → Local system response due to Impulse transient



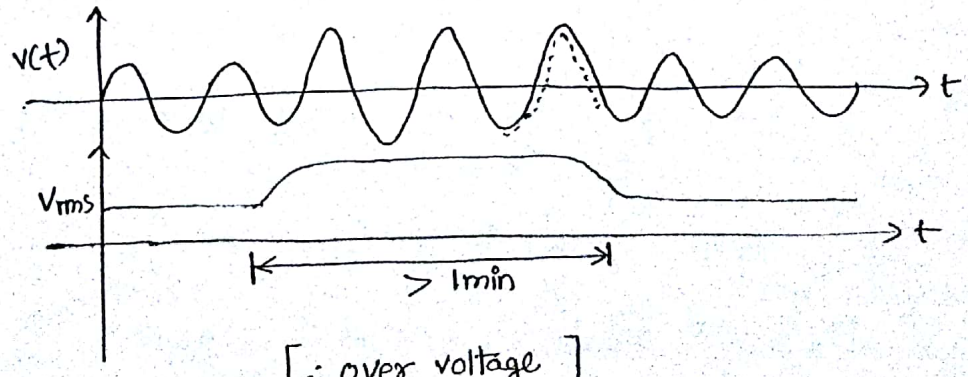
(5) Long duration voltage variation:-

- A voltage variation is considered to be long duration when the duration is greater than 1 min.
- Long duration voltage variations are either over voltage or under voltages
- Long duration voltage variations are generally not the result of system faults, but are caused by load variations on the system and system switching operations.
- Such variations are Typically displaced as plots of RMS voltage versus time.
- Over voltage:— ($1.1\ pu < V_{RMS} < 2.1\ pu$)
  - An over voltage is an increase in the Rms Ac voltage, in the limits $1.1\ pu < V_{RMS} < 2.1\ pu$ at the power frequency for a duration longer than 1 min.
  - over voltages are usually the result -

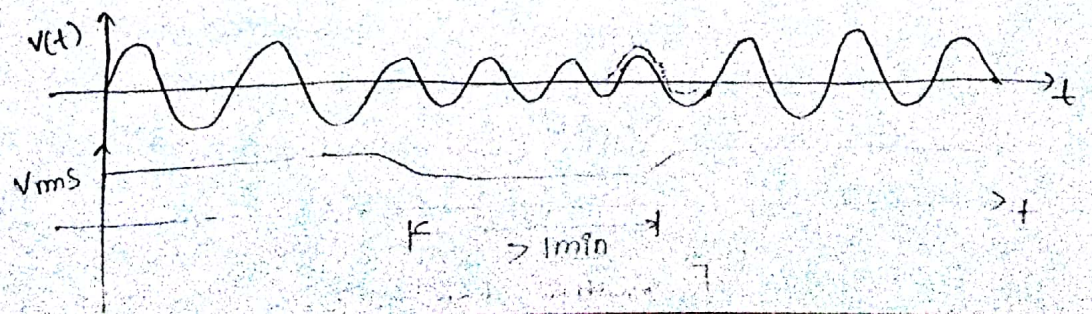
- of switching-off a large load or energiging a capacitor bank
- The over voltages result because either the system is too weak for the desired voltage regulation or voltage controls are inadequate.
- Incorrect tap setting on transformers can also result in system over voltages.

- under voltage :- ($0.1 < V_{rms} < 0.9$)
  - An under voltage is a decrease in the rms AC voltage to less than 0.9 p.u at the power frequency for a duration longer than 1 min
  - under voltages are the result of switching events that are the opposite of the events that cause over voltages
    - A ~~long~~ load switching on (or) a capacitor bank switching off can cause an under voltage

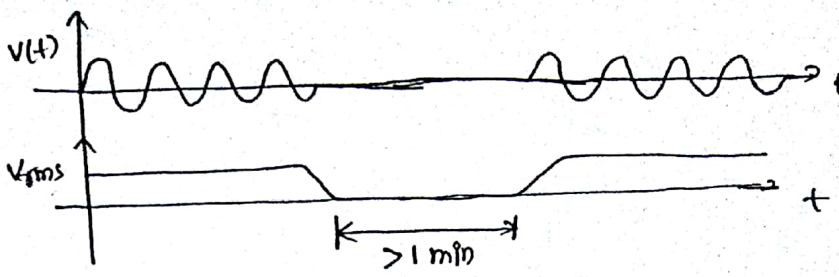
- diagrams for over voltage and under voltage



[∴ over voltage]



- **Sustained interruptions:-**
  - When the supply voltage has been zero for a period of time in excess of 1 min is called sustained Interruption.



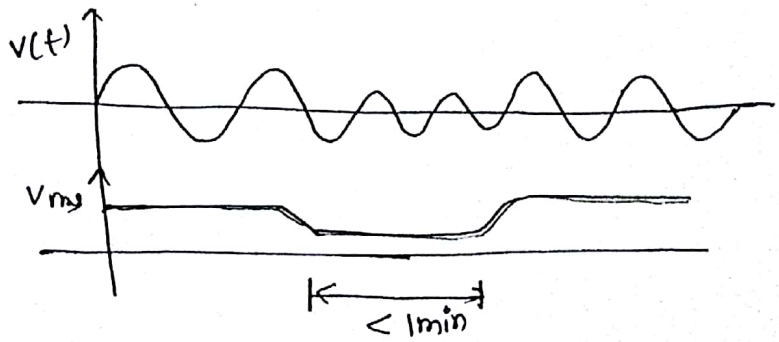
  - Voltage Interruptions longer than 1 minute are often permanent and require human intervention to repair the system for restoration.

(6) **Short duration voltage variations:-**

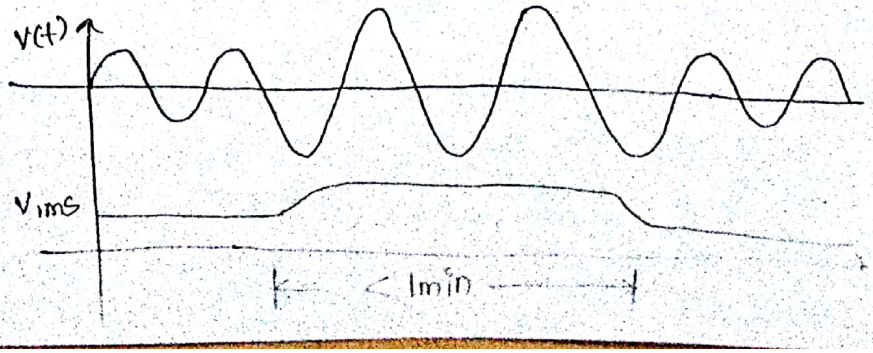
- Variations in voltage are instantaneous and momentary (or) temporary.
- Short duration voltage variations are caused by the fault conditions and loose connections in power wiring
- Depending on the fault location and system conditions, the fault can cause either temporary voltage drops (sags), voltage rises (swells) or a complete loss of voltage.
- The Impact on the voltage during the fault condition is of the short duration variation until the protective devices operate to clear the fault.
- **Interruption:-** ($V_{rms} < 0.1$ p.u)
  - An interruption occurs when the supply voltage or load current decreases to less than 0.1 p.u for a period of time not exceeding 1 minute.
  - Interruptions result of faults, equipment failure, control malfunction.

- Delayed operation of protective devices cause a momentary or temporary interruptio

- **Sags :-** (dip)
  - A sag is a decrease to between 0.1 and 0.9 P.U in Rms voltage or current at the power frequency for durations from 0.5 cycle to one minute.
  - A short duration voltage variation
  - Voltage sags are associated with system faults
  - mainly caused by energigation of heavy loads (or) starting of Large motors.
  - Induction motors will draw 6 to 10 times its full load current during starting results voltage sags and gradually returns to normal in about 3 Sec.
  -



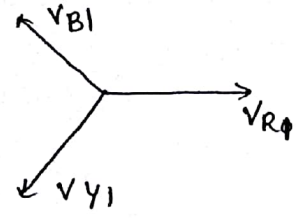
- **Swells :-**
  - A swell is defined as an increase to between 1.1 to 2.1 P.U in rms voltage or current at the power frequency for duration from 0.5 cycle to 1 min.
  -



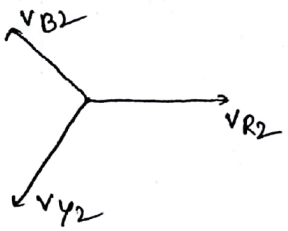
- Swell → voltage rise in other healthy phases while LG fault in one phase.
- switching off large load (or) connecting a large capacitor banks can cause swells.
- magnitude of voltage swell depends on fault location, system impedance, grounding.
- Magnitude is high in ungrounded systems than grounded.

(7) Voltage Imbalance (unbalance) :-

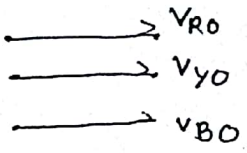
- The ratio of either the negative or zero sequence component to the positive sequence component can be used to specify the percent unbalance



Positive Sequence



Negative Sequence



Zero sequence

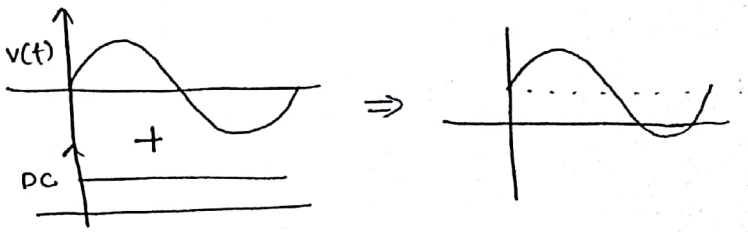
$$V_R = V_{RO} + V_{R1} + V_{R2}$$
$$V_Y = V_{Y0} + V_{Y1} + V_{Y2}$$
$$V_B = V_{B0} + V_{B1} + V_{B2}$$

$$\% \text{ Imbalance} = \frac{V_0}{V_1} \times 100 \quad (\text{or}) \quad \frac{V_2}{V_1} \times 100$$

- Voltage imbalance is the result of blown fuses in one phases
- Single phase loads can cause voltage imbalance greater than 5%.

⑧ waveform distortion :-

- waveform distortion is defined as a steady state deviation from an ideal sine wave of power frequency.
- Types of waveform distortion
  - DC off set
  - Harmonics
  - Inter harmonics
  - Notching
  - Noise.

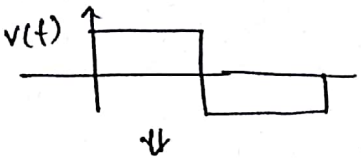
- DC offset :-
  - The poesence of a DC voltage or current in an ac power system is termed as DC offset
  - This is the result of asymmetry operation of electronic power converters.
  - 

  - Direct current in AC network can saturate Transformer core. This cause additional heating and loss of transformer life.
  - also DC off set cause electrolytic erosion of grounding electrodes and other connections.
- Harmonics :-
  - Harmonics are sinusoidal voltages (or) current having frequencies that are integer multiples of frequency (50Hz) (50X2 Hz, 50X3 Hz, 50X4 Hz ....)
  - periodically distorted waveforms can be decomposed into a sum of fundamental and the harmonics.

- Power electronics loads are cause of harmonics
- "Total harmonic distortion" is a measure of the effective value of harmonic distortion.
- $V_{rms} = \sqrt{V_1^2+V_2^2+V_3^2+V_4^2\ldots\ldots}$

$$V_r^2 = V_1^2+V_2^2+V_3^2+V_4^2+\ldots$$

$$THD = \sqrt{\frac{V_r^2}{V_1^2}-1} = \sqrt{\frac{V_2^2+V_3^2+V_4^2+\ldots}{V_1^2}}$$

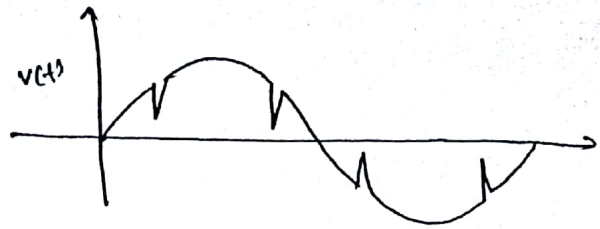
- 

$$v(t) = a_0 + \sum_{k=1}^{n} (a_k \cos k\omega t + b_k \sin k\omega t)$$

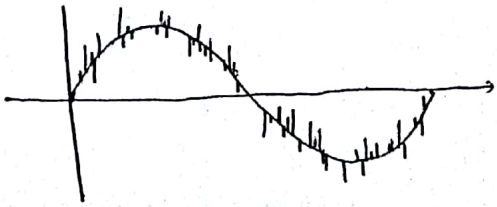
$$K = 1, 2, 3, 4 \ldots\ldots n$$

- Inter harmonics :-
  - Voltages or currents having frequency components that are not integer multiples of the frequency (50X1.3 Hz , 50X2.5Hz ...)
  - sources of Interharmonics are
    - static frequency converters
    - cyclo converters
    - Induction furnaces
    - arcing devices.
  - Cause severe resonances on the power systems.

- **Notching :-**
  - Notching is a periodic voltage disturbance caused by normal operation of power electronic devices when current is commutated from one phase to another.
  - During this period there is a momentary short CKT between two phases pulling the voltage as close to zero



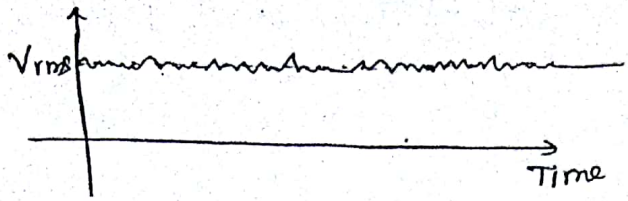
- **Noise :-**
  - Noise is defined as unwanted signals with broadband spectral content lower than 200KHz super imposed upon the power system voltage or current.
  - caused by power electronic devices, control CKTS, arcing equipment.
  - Noise consists of any unwanted distortion of power signal that can't be classified as harmonic distortion or transients.



(9) **Voltage fluctuations :-**

- Voltage fluctuations are symmetric variations of the voltage envelope (or) a series of random voltage changes.
- The magnitude of which doesn't normally exceed the range of $0.99\ p.u \leq V_{rms} \leq 1.01\ p.u$

- Loads that exhibit continuous, rapid variations in load current magnitude can cause voltage variations.



- magnitudes are in between 0.5% to 1% and the frequencies in the range 6Hz to 8 Hz.

(10) Power frequency Variations :—

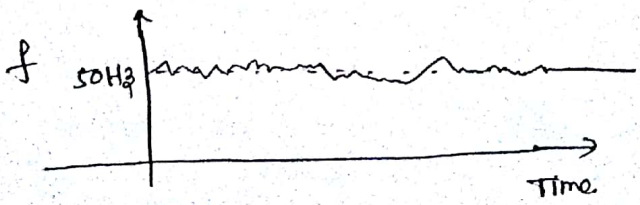
- PFV are defined as the deviation of power system fundamental frequency (50 Hz)
- The power system frequency is directly related to the rotational speed of the generators

$$N = \frac{120f}{P}$$

$$N \propto f$$

load ↑ → speed ↑ → frequency ↑

- main reasons are
  - faults on bulk power transmission
  - Large load is disconnected
  - Large source of generation is going offline.



- Limits are ±1%.